Endogenous transport prices and trade imbalances

Jonkeren, O.E.; Demirel, E.; van Ommeren, J.N.; Rietveld, P.

published in
Journal of Economic Geography
2011

DOI (link to publisher)
10.1093/jeg/lbq002

document version
Publisher's PDF, also known as Version of record

Journal of Economic Geography **11** (2011) pp. 509–527
Advance Access Published on 4 February 2010

doi:10.1093/jeg/lbq002

Endogenous transport prices and trade imbalances

Olaf Jonkeren[*,‡], *Erhan Demirel*[*], *Jos van Ommeren*[*†] *and Piet Rietveld*[*†]

[*]Department of Spatial Economics, VU University Amsterdam, De Boelelaan 1105, 1081 HV Amsterdam, The Netherlands
[†]Research Fellows Tinbergen Institute
[‡]Corresponding author: Olaf Jonkeren, Department of Spatial Economics, VU University Amsterdam, De Boelelaan 1105, 1081 HV Amsterdam, The Netherlands. *email* <ojonkeren@feweb.vu.nl>

Abstract

According to economic theory, imbalances in trade flows affect transport prices, because (some) carriers have to return without cargo from the low-demand region to the high-demand region. Therefore, transport prices in the high-demand direction have to exceed those in the low-demand direction. This implies that transport costs, and therefore trade costs, are fundamentally endogenous with respect to trade imbalances. We study the effect of an imbalance in trade flows on transport prices using micro-data on trips made by carriers in the inland waterway network in North West Europe. We find that imbalances in trade flows have substantial effects on transport prices. We estimate that a one standard deviation increase in the region's trade imbalance (the ratio of export and import cargo flows) increases the transport price per tonne of trips departing from this region by about 7%.

Keywords: imbalance, trade, inland waterway transport, backhaul problem, transport price
JEL classifications: D21, D41, F14, L92, R41
Date submitted: 16 March 2009 **Date accepted:** 5 January 2010

1. Introduction

Transport costs play a fundamental role in the determination of the location of regional economic activities (see, e.g. Krugman, 1991, 1998; Ottaviano and Puga, 1998; Neary, 2001). A characteristic assumption in these studies is that transport costs are exogenous. However, recently, a number of studies have emphasized that transport costs are 'endogenous'. In particular, we refer to the recent studies by Behrens and coauthors (Behrens and Gaigné, 2006; Behrens et al., 2006, 2009). For example, Behrens et al. (2006) introduced the presence of density economies into a new economic geography model by assuming that unit-shipping costs decrease with the aggregate volume of trade. Endogeneity of transport costs is also clearly important for studies on international trade. For example, Anderson and van Wincoop (2004) stress the need to deal with this issue in studies on trade. Note that, although transport costs, i.e. the physical costs of a shipment, are only a share of trade costs (Duranton and Storper, 2008), transport costs are generally thought to be the most important trade cost 'within' countries and one of the most important components of trade costs 'between' countries. This certainly applies to trade within the EU where artificial trade barriers are absent or limited. According to Sánchez et al. (2003) and Limão and Venables (2001), artificial trade barriers are reduced to low levels as a result of trade liberalization. Therefore, it is plausible that the relative importance of transport costs in total trade costs has increased in the recent decades.

There are a number of reasons why transport costs are endogenous [for recent studies which discuss this issue, see Duranton and Storper (2008) and Anderson (2008)]. One reason is that the unit-shipping costs decrease with the volume of trade due to the presence of density economies (e.g. Behrens et al., 2006). Another reason is that industry location is endogenous (see Behrens et al., 2009). The current article addresses another aspect, i.e. that the endogeneity of transport costs results from an imbalance in terms of trade volumes between two regions (Boyer, 1998; Behrens and Picard, 2008). This causes the transport price in one direction to exceed the price in the opposite direction when 'a positive proportion of carriers are required to return without paid cargo'.[1] One of the implications of the imbalance is that, ceteris paribus, unit-shipping costs increase with trade. It is therefore theoretically ambiguous what the net effect is of a change in the traded volume on trade costs as it depends on what type of effect dominates, density economies or imbalance. In one market, the net effect may be negative while for other markets it may be positive.

The effect of imbalance on freight prices may potentially be very large. For example, the freight price for a 1 TEU (20-foot equivalent unit) container of plastic bags from Shanghai to San Francisco is currently $2065, whereas its backhaul price is $1111. So, the backhaul price is roughly 50% less than the fronthaul price (this kind of information is publicly available on freight price websites such as www.freight-calculator.com). Likely, the main explanation for this observation is that the merchandise goods flow from China to the USA is much larger than the other way around (in value terms, the flow from China is four times that of the return flow).

In the current study, we focus on price formation in a spatial inland waterway transport network for predominantly dry bulk cargo. This market is highly competitive with thousands of small carriers (see Table 1), the majority of those carriers being one-ship enterprises. In addition, the carriers offer a relatively homogenous product (transport of different types of bulk cargo), and shippers may easily switch from one inland waterway carrier to another. In the inland waterway sector, imbalances in transport flows are frequently observed. Imbalances are caused by regional differences in demand for transport. For example, in Europe, most seaports, such as Rotterdam (in the Netherlands) and Antwerp (in Belgium), receive more cargo (iron ore, coal, etc.) from overseas locations than they dispatch to these locations. This implies that more

Table 1. Number of registered barges per Rhine-country per segment on 31 December 2006

	Netherlands	Germany	France	Belgium	Switzerland	Luxemburg	Total
Dry cargo	3828	1803	1316	1272	20	13	8252
Tanker	767	422	77	223	37	18	1544
Total fleet	4595	2225	1393	1495	57	31	9786

Source: CCNR and European Commission (2007).

1 For an early discussion of this phenomenon, usually called the 'backhaul problem', see Pigou (1913).

cargo is transported from the seaport regions to the hinterland regions than in the opposite direction, which causes an imbalance in inland shipping trade flows.

This is not the first empirical study to focus on transport prices. There is an extensive literature, mainly focusing on maritime transport, in which the determinants of transport prices are analysed, but imbalances in transport flows are usually ignored. We are aware of four studies in which the effect of an imbalance in transport flows on maritime shipping prices has been examined empirically (Clark et al., 2004; Márquez-Ramos et al., 2005; Wilmsmeier et al., 2006; Blonigen and Wilson, 2008). However, in these studies, imbalance is assumed to be exogenous, which is at odds with theory [note that Clark et al. (2004) and Márquez-Ramos et al. (2005) allow for density economies by including aggregate trade volume as an explanatory variable and treat trade volume as an endogenous variable].

We estimate the marginal effect of an imbalance in transport flows on the unit transport price of trips in the inland waterway transport market in North West Europe. We mention some major differences between the current study and the four transport price studies mentioned earlier. First, these studies use information on imbalances of bilateral routes, while we also take into account characteristics of the network using a spatially weighted regional imbalance measure, in line with other economic applications of spatial problems [see, for example, Boarnet (1994a, 1994b) and Rice et al. (2006)]. Spatial weighting implies that we take the imbalances in other (particularly adjacent) regions into account when determining the imbalance for a specific region. Second, to our knowledge, we are the first to consider imbalance as an endogenous variable, using the presence of sea-ports as instruments. Third, we empirically capture density economies in a different, and arguably more fundamental, way than Clark et al. (2004) and Márquez-Ramos et al. (2005). Using a broad definition of density economies such as used by Brueckner et al. (1992), density economies arise, because a higher traffic density on a route allows the carrier to use larger vessels and to operate this equipment more intensively (at higher load factors). In addition, higher traffic densities on a route allow for a more intensive and efficient use of the port facilities that serve that route implying lower time costs per unit handled. As we have a very rich data set, we are able to capture density economies by means of three trip-specific control variables: vessel size, load factor and travel time. The travel time of a trip includes the time of loading, transporting and unloading the cargo.[2] Fourth, our study concerns inland waterway transport, which comes close to the 'ideal' standard perfect competitive market, while previous studies focus on the maritime transport sector, where market power of carriers is potentially an important issue as argued by some studies (Sjostrom, 2004).

The importance of inland waterway transport as part of the overall transport sector for the regional economy is determined by geographical constraints. Only in those regions where the natural infrastructure offers sufficient opportunities does inland waterway transport play a significant role in inland transport. Examples of such regions include parts of Europe (the rivers Rhine, Danube and their tributaries), the USA (the Great Lakes area and the Mississippi river) and China (the Yangtze and the Pearl River).

2 Large ports (which usually have more efficient handling facilities), may induce relatively short (un)loading times, leading to shorter travel times. On the other hand, higher volumes may imply density diseconomies in case of congestion.

The river Rhine is the most important trade river in Europe as it connects large economically important areas within and between the Netherlands and Germany. The Netherlands and Germany are neighbouring countries and trade between these countries is intensive. In 2005, Germany was the most important export country for the Netherlands, and the Netherlands was the fifth export country for Germany.

The river Rhine has its source in Switzerland in the Alps and runs through the Ruhr area, one of the most industrialized areas in Germany, to Rotterdam, in the Netherlands, one of the world's major seaports, where it flows into the North Sea. In the Rhine corridor, inland waterway transport competes heavily with road and rail transport. In general, inland waterway transport is cheaper (per tonne-kilometre), but slower than the other modes. In 2005, 58% of all bilateral inland trade, measured in tonnes, from the Netherlands to Germany, was transported by inland waterways. In the opposite direction, inland waterway transport accounted for 41% (CBS, 2008; TLN, 2007).[3] Hence, trade costs between the Netherlands and Germany strongly depend on inland waterway transport prices. So, an understanding of price formation in the inland waterway transport market is fundamental to understand the endogeneity of trade costs between the Netherlands and Germany. Next, Section 2 describes the data and formulates the empirical model. Section 3 presents the results, and, finally Section 4 makes some concluding remarks.

2. Methodology and data

2.1. Methodology

Our aim is to estimate the effect of an imbalance in transport flows on the transport price. In a multi-region network, one may measure imbalance for a trip between two regions at the level of the 'route' (for example, for each route, one can calculate the ratio of the cargo flow in one direction and the cargo flow in the other direction) or at the level of the 'region' (for example, for each region, one can calculate the ratio of the export and import cargo flows). In the current work, we will measure imbalance at both levels.

At the 'route level', imbalance is measured bilaterally; so, on every route, the imbalance is measured by the ratio of the cargo flow in one direction and the cargo flow in the opposite direction. Hence:

$$M_{ij} = \frac{T_{ij}}{T_{ji}}, \tag{1}$$

where M_{ij} is the 'route imbalance' for a trip from region i to region j, T_{ij} is the number of trips 'with cargo' from i to j and T_{ji} is the number of trips 'with cargo' from j to i. In our application, we will use the logarithm of $M_{ij.}$

In a multi-region network, carriers may not move back and forth between two regions but will make more complicated journeys as they cruise through the network for shipments (we have examined this for a randomly selected sample of carriers in our

3 In 2005, in total, 127 million tonnes were transported from the Netherlands to Germany, and 73 million tonnes the other way around implying an imbalance ratio of 0.57. For inland waterway transport, this ratio is 0.41. For the survey data used in the current article, we find a ratio of 0.49, indicating that our data is quite representative.

data; it appears that only 1 of 50 carriers immediately travels back to the region of origin). Measuring imbalance at the level of 'routes' will not adequately capture the effect of an imbalance in transport flows on transport prices. It is straightforward to give relevant examples.

An illuminating example is when carriers transport goods from A to B, but a positive proportion of these carriers moves from B to C (possibly without cargo), and then transport cargo from C to A. In this example, the transport price from A to B depends not only on the demand for transport from A to B, and from B to A, but also on the demand characteristics of the B to C and C to A routes.[4] Measuring imbalance at the level of routes implies that only the demand for transport from A to B, as well as the demand for transport from B to A, is incorporated in the measure in order to explain the transport price for the A to B trip. It follows that an empirical analysis of the effect of an imbalance in transport flows on transport prices in multi-region networks which only includes measures of route imbalance is likely to underestimate the importance of the effect of an imbalance in transport flows on transport prices, because the route imbalance does not adequately capture imbalance at the network level. In other words, if the difference between the route imbalance and the theoretically appropriate imbalance variable is random error, then the estimated effect is biased towards zero; see Verbeek (2000, p. 120). This implies that it is important to measure imbalance taking network characteristics into account.

In a multi-region network, there does not exist one generally accepted imbalance measure, as this measure requires complete information about the demand functions of all routes, which is not available. We will improve on the route imbalance variable by introducing a measure that takes into account how close regions are located to each other. This measure is called the region imbalance variable—as opposed to the route imbalance concept—and is defined as the ratio of the export and import cargo flows in a region. To take the geographical relationship between regions into account, we construct a spatially weighted region imbalance variable, I_i, which is defined as follows:

$$I_i = \frac{\sum_j w_{ij} O_j}{\sum_j w_{ij} D_j} \tag{2}$$

where O_j is the number of trips 'with cargo' departing from region j, D_j is the number of trips 'with cargo' arriving in region j and w_{ij} is a weighting factor.[5] The principle of weighting is used in many spatial applications (see Boarnet, 1994a,b; Rice et al., 2006). One may define w_{ij} in several ways. For example, if $w_{ii} = 1$ and $w_{ij} = 0$ for $i \neq j$, then regions other than i do not play a role in the determination of the imbalance in region i,

4 Another example is to presume that there exists demand for transport from region B to C (but not from C to A). The transport price from A to B then depends not only positively on the demand for transport from A to B and negatively on the demand for transport from B to A, but also negatively on the demand for transport from region B to C.

5 An alternative way of measurement of I_i is to measure O_j and D_j in terms of the amount of cargo (in tonnes) instead of the number of trips with cargo. Because the correlation between the region imbalance variable measured in number of trips with cargo and the same variable measured in tonnes is close to one (0.98), it appears that the results are insensitive in this respect.

so in this case $I_i = O_i/D_i$. In our empirical specification, we define w_{ij} as follows:

$$w_{ij} = \frac{F(d_{ij})}{\sum_j F(d_{ij})}, \text{ so that } \sum_j w_{ij} = 1 \text{ for all } i. \tag{3}$$

We will use $F(d_{ij}) = e^{-\gamma d_{ij}}$, so F can be interpreted as an exponential-decay factor, d_{ij} is the distance between regions i and j and γ is a decay parameter.[6] One difficulty is how to obtain a value for γ. In our application, we will not arbitrarily fix γ as is often done in empirical studies. Instead, the parameter γ will be estimated using information about the distance navigated 'without' cargo by inland waterway carriers before starting a new trip with cargo. The weight w_{ij} may thus be interpreted as an inverse indicator of economic distance: the shorter the distance between two regions, the higher the probability that trips without cargo will be made to collect cargo from a neighbouring region. We will now give an—admittedly simple—example for which holds that the weighted region imbalance variable, I_i, is more appropriate than the route imbalance variable. We will suppose that there are only three regions: A, B and C.

Suppose there is demand for transport between regions A and B as well as between A and C, but not between B and C. Suppose further that the distance between regions B and C is negligible, and the distances between A and B and A and C are so large that carriers would hardly make an empty trip from B to A (or C tot A) to pick-up cargo.[7] Because regions B and C are close to each other, we have essentially a two-region network, so that the appropriate measure of imbalance for regions B and C is the ratio of the sum of the departing cargo from B and C to the sum of the arriving cargo in B and C (Boyer, 1998). Using the weights for regions A, B and C, the region imbalance indicator I_i as defined in equation (2) exactly measures the imbalance in the correct way, whereas the route imbalance variable M_{ij} as defined in Equation (1) does not (as it ignores that B and C are essentially one region). We emphasize that this does not prove that the region imbalance measure is superior to the route imbalance measure for all possible network configurations but, in the present configuration, it certainly is.

In networks with more than two regions, transport prices are expected to depend positively on the imbalance in the region of 'origin' as well as negatively on the imbalance in the region of 'destination'. So, we will use 'two' indicators of region imbalance (only in a two-region network, there is no distinction between measuring at the level of the region or at the level of the route). We aim to estimate the effect of the imbalance in the 'origin region', denoted as I_i and the imbalance in the 'destination region', denoted as I_j on the transport price. Later on, we will show in the empirical application that these two imbalance variables have about opposite effects. Therefore, we will use a more parsimonious measure of the imbalance for the pair of regions i and j, I_{ij}, which we will call the 'region imbalance difference', and which is defined by the

6 The use of the distance-decay principle is widespread in network modelling. For example, Hojman and Szeidl (2008) introduce a model of network formation in which benefits from connections decay with distance.

7 In this case, the weights are determined as follows: $w_{BB} = w_{CC} = w_{BC} = w_{CB} = 0.5$, $w_{AB} = w_{BA} = w_{AC} = w_{CA} = 0$ and $w_{AA} = 1$.

ratio of the imbalance in the origin region and the imbalance in the destination region:

$$I_{ij} = \frac{I_i}{I_j} \tag{4}$$

The use of I_{ij} in the price equation implies that the effects of I_i and I_{ij} are assumed to be identical and that the effect of I_j is inversely proportional to that of I_i.

2.2. Data

We use a data set, the Vaart!Vrachtindicator, which contains detailed information about trips made by inland waterway carriers in North West Europe [more information can be found on the website www.vaart.nl, as well as in Jonkeren et al. (2007)]. The carriers report information (via the Internet) about their trips, such as the transport price, region and date of (un)loading, capacity of the ship, number of tonnes transported and type of cargo. We distinguish between trips from and towards 15 regions, using a classification as reported by the carriers (see Figure 1). Information on the region imbalance values for the 15 regions can be found in appendix (Table A1).

The data set contains information on inland waterway transport trips that occur in the spot market where the price for transport is negotiated per trip. In our application, we use the logarithm of the price per tonne. Inland waterway transport enterprises that operate in the long-term market (and work under contract) are not included in the data set. The data therefore cover only a limited part of the whole inland waterway transport market, but descriptives of our imbalance variable calculated for the Netherlands and Germany are consistent with publicly available data. This suggests that the sample is representative in terms of imbalance variables.

The database contains 21,865 observations of inland waterway trips in North West Europe, reported between January 2003 and January 2007. For about 6000 trips information on the stream direction, which we will use as control variable, is difficult to determine. Therefore, these trips are excluded from the analysis. Table A2 offers the same descriptives as in Table 2, but now including the mentioned 6000 trips. With these extra trips, we are able to distinguish between 20 regions instead of 15 regions. The descriptives in Table A2 and the analysis based on 20 regions (which generates similar results and can be received upon request) show that our sample is not selective. Observations with missing information, a few extreme outliers, and observations that concern container transport were also excluded. We exclude observations referring to container transport, because the price for container transport is expressed as the transport price per container instead of the transport price per tonne. Furthermore, we excluded a limited number of observations for which the measurement of the route imbalance is unreliable as M_{ij} may contain substantial measurement error if the number of trips between two regions is small.[8] Ultimately, 10,794 observations (of which 10,324 trips concern transport of dry bulk and 470 trips refer to wet bulk) are used for multivariate analysis.

8 For the selected sample, the number of trips between two regions exceeds 96 for all routes, and so this is not an issue in the current application.

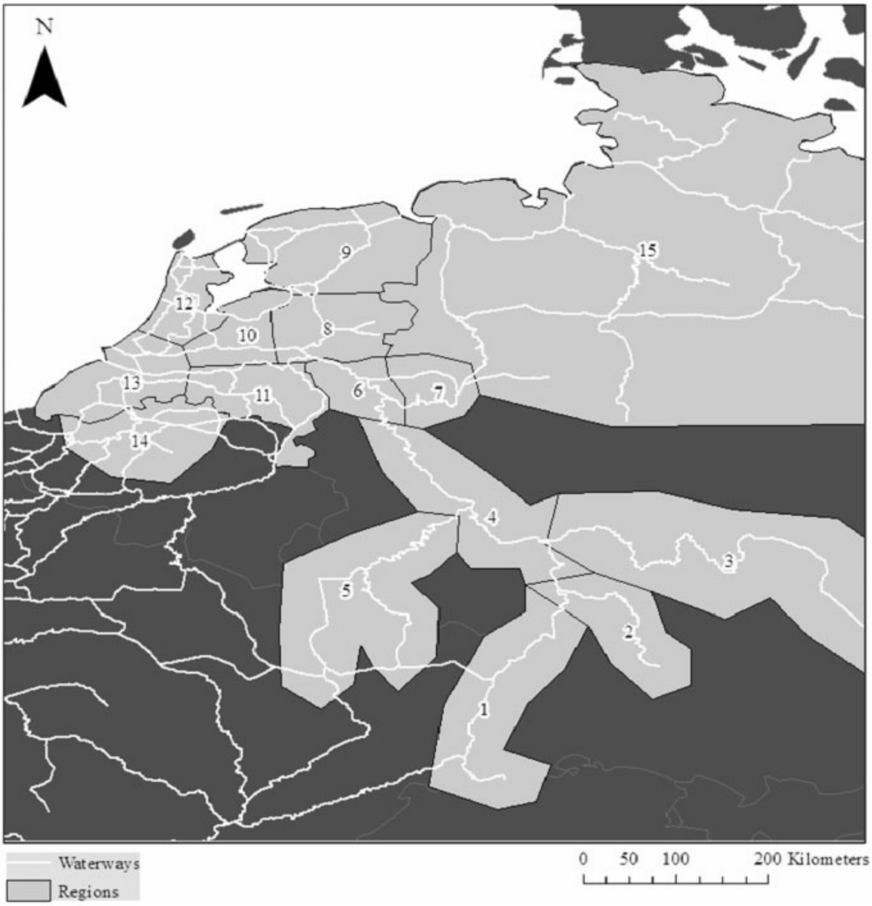

Figure 1. Regions in the inland waterway transport market in North West Europe.
Note: (1) Upper Rhine, (2) Neckar, (3) Main/Danube, (4) Middle Rhine, (5) Moselle/Saar, (6) Ruhr, (7) West German Canals, (8) Netherlands East, (9) Netherlands North, (10) Netherlands Centre, (11) Netherlands South, (12) Amsterdam Port Area, (13) Rotterdam Port Area, (14) Antwerp Port Area, and (15) North German Canals.

The descriptives of key variables used in the analysis are shown in Table 2. The average trip (including loading and unloading time) takes about 5 days. The average price per tonne transported is €8.13.

To calculate the region imbalance variable, we need information about the decay parameter γ. This parameter has been estimated on the basis of the carriers' distribution of distances navigated without cargo before starting a trip (see Figure A1). To estimate γ in this way is useful, because after a carrier has been unloaded, carriers frequently travel 'without cargo' to another region from where the next trip with cargo starts. In one of three trips, carriers navigate more than 100 km without cargo before starting a new trip. In one of nine trips, carriers navigate even more than 200 km without cargo. The average distance navigated without cargo is about 95 km, which is substantial, compared with the average distance navigated with cargo, which is 569 km

Table 2. Descriptives of key variables of transports flows and trip data

Variable	Minimum	Maximum	Mean	SD
M_{ij} (route imbalance)	0.27	100.00	7.32	14.92
$\log(M_{ij})$	−1.32	4.61	1.14	1.23
I_{ij} (region imbalance difference)	0.45	2.76	1.64	0.71
$\log(I_{ij})$	−0.81	1.02	0.37	0.56
I_i (region imbalance, origin)	0.74	1.81	1.44	0.39
$\log(I_i)$	−0.30	0.59	0.32	0.31
I_j (region imbalance, destination)	0.66	1.81	1.00	0.34
$\log(I_j)$	−0.42	0.59	−0.05	0.30
Price per tonne (in €)	1.45	54.55	8.13	5.37
Travel time (in days)	1.00	30.00	5.25	2.27
Distance trip (in km)	97.00	4000.00	569	271
Distance navigated without cargo (in km)	0.00	908.00	95.15	97.03

Source: The Vaart!Vrachtindicator (2003–2007).

(see Table 2). The estimated value of the parameter γ related to the exponential distribution of distances without cargo equals 0.011 (see Figure A1).

As an illustration of the effects, we aim to capture, it may be useful to focus on transport prices in one specific region. Transport prices for trips originating from the Rotterdam port area are 32% higher than prices for trips arriving here, whereas the (weighted) number of trips with cargo departing from the port of Rotterdam is about two times higher than the (weighted) number of trips with cargo arriving in the port of Rotterdam (see Table A1). Although only suggestive, it seems that the effect of imbalance on transport prices may be substantial.

Our main focus is now to examine the effect of the route and region imbalance difference—M_{ij} and I_{ij}—on transport prices.[9] In addition to the two imbalance measures mentioned earlier, we include a large number of control variables in the price equation to be estimated:

$$\log(Y_{rijt}) = \beta_1 \log(M_{ij}) + \beta_2 \log(I_{ij}) + \beta_3 X_{rijt} + \varepsilon_{rijt} \tag{5}$$

where Y_{rijt} denotes the transport price per tonne for trip r from region i to region j at time t, M_{ij} is the route imbalance for a trip between regions i and j, I_{ij} is the region imbalance difference for a trip between regions i and j, X_{rijt} refers to observed explanatory variables of the trip, ε_{rijt} denotes unobserved random error and β's are coefficients to be estimated.

The control variables in X_{rijt} include a time trend, travel time[10] and distance, both in logarithms; ship size (categorized by five dummy variables); 47 bulk cargo dummies (e.g. coal, gravel, fertilizer, wheat, corn and soya), the fuel price in logarithm and the

9 To identify the effect of an imbalance in transport flows on transport prices, we do *not* exploit any time-variation in regional imbalances, because much of the time-variation observed in the imbalance variables is due to measurement error, which induces a strong measurement error bias.

10 For 76% of the observations, we have the trip-specific travel time. For the other observations, this variable is not reported, and so we use the region-to-region specific average travel time. This introduces some measurement error in this variable.

load factor, defined as the ratio of the tonnes transported and the capacity of the inland vessel, also in logarithm. Furthermore, we include water level as an explanatory variable by means of nine dummies. As shown by Jonkeren et al. (2007), water levels have strong effects on prices, as low-water levels impose restrictions on the load factors of inland waterway vessels. Water level is measured at Kaub (a town in Germany at the East bank of the river Rhine), because Kaub is the critical bottleneck in terms of the load factor for trips that take place in the river Rhine basin. As not all trips pass Kaub, we make a distinction between the effect of the water level for trips that pass Kaub and that for trips that do not pass Kaub. The costs of navigation may depend on the navigation direction as downstream navigation requires less fuel than upstream navigation. We distinguish between five different navigation directions. Finally, we include a dummy variable for each month (11 dummies) to control for unobserved monthly changes in supply and demand factors. A discussion of the results of our analysis will be presented in Section 3.

3. Results

3.1. The effect of imbalance on the transport price

Equation (5) has been estimated using ordinary least squares (OLS) as well as using instrumental variables. As the imbalance variables are aggregate measures, we allow for clustering on the basis of the region of destination. This prevents the standard errors to be biased downwards (Moulton, 1990).[11] Clustering on the basis of region of origin or on the basis of routes generates almost identical results. However, clustering on the basis of the region of destination is the more conservative procedure, in the sense that the standard errors are larger, and so we opt to report this way of clustering.

OLS estimates of the effect of imbalance may be biased due to endogeneity of the imbalance variable, because transport prices and flows are simultaneously determined. Hence, shippers in regions with a, for them, favourable imbalance (i.e. in regions where supply of carriers is relatively large) will increase their demand for inland waterway transport capacity, because the transport price for trips that depart from that region is low. In the case of inland waterway transport, the endogeneity of imbalance may be argued to be important, as the inland waterway transport sector competes with the rail and road sectors for the same cargo. On the other hand, one may think that endogeneity is not an issue, as, especially in case of transport over long distances, the cost advantage of using inland waterway transport instead of alternative transport modes is substantial. Furthermore, as the inland waterway transport costs are only a small part of the overall production costs of the goods, it may be thought that demand for transport is quite inelastic with respect to the unit price of transport. We are aware of a number of recent studies, which demonstrate that demand for inland waterway transport in Europe is inelastic. For example, Jonkeren et al. (2007) report that the demand elasticity is about −0.5.

We use an instrumental variable approach to address the endogeneity of the imbalance variables. Our instruments are two sea port dummies, which measure whether a trip starts or ends in a sea port. These instruments can be argued to be exogenous with

11 Not allowing for clustering results in standard errors, which are about four times smaller for the aggregate variables.

Table 3. Estimation results for the transport price in the inland waterway transport market

	OLS		IV	
Explanatory variables	Coefficient	SE	Coefficient	SE
Constant	−3.342	0.248	−3.295	0.271
Region imbalance difference, log(I_{ij})	0.116	0.038	0.296	0.085
Route imbalance, log(M_{ij})	−0.013	0.006	0.008	0.013
Log(travel time)	0.086	0.013	0.079	0.012
Log(distance)	0.689	0.037	0.695	0.037
Time trend/1000	0.278	0.036	0.276	0.037
Log(fuel price)	0.027	0.061	0.031	0.061
Log(load factor)	−0.421	0.048	−0.428	0.048
Vessel size				
0–1000 tonnes	0.313	0.016	0.319	0.015
1000–1500 tonnes	0.208	0.015	0.213	0.015
1500–2000 tonnes	0.127	0.017	0.130	0.017
2000–2500 tonnes	0.080	0.013	0.083	0.013
>2500 tonnes	Reference		Reference	
Navigation direction				
Upstream	0.202	0.053	0.006	0.074
Up-and-downstream	0.229	0.038	0.087	0.066
Partly upstream	0.149	0.063	−0.035	0.080
Partly downstream	0.051	0.036	−0.003	0.036
Downstream	Reference		Reference	
Water level, trips via Kaub				
<180	0.433	0.032	0.424	0.032
181–190	0.325	0.042	0.317	0.043
191–200	0.275	0.024	0.272	0.023
201–210	0.249	0.030	0.245	0.030
211–220	0.163	0.027	0.156	0.025
221–230	0.133	0.026	0.129	0.025
231–240	0.111	0.020	0.108	0.019
241–250	0.066	0.017	0.066	0.017
251–260	0.029	0.009	0.030	0.009
≥261	Reference		Reference	
Water level, trips not via Kaub				
<180	0.326	0.057	0.327	0.061
181–190	0.283	0.049	0.283	0.053
191–200	0.179	0.042	0.179	0.047
201–210	0.158	0.044	0.162	0.048
211–220	0.103	0.042	0.103	0.045
221–230	0.042	0.037	0.043	0.043
231–240	0.043	0.035	0.045	0.040
241–250	0.020	0.039	0.025	0.043
251–260	0.008	0.033	0.011	0.040
≥261	−0.019	0.032	−0.015	0.040
Month dummies				
January	Reference		Reference	
February	−0.066	0.011	−0.068	0.012
March	−0.133	0.016	−0.133	0.016
April	−0.098	0.015	−0.100	0.016
May	−0.085	0.017	−0.087	0.018
June	−0.082	0.023	−0.084	0.024
July	−0.068	0.025	−0.069	0.026
August	−0.132	0.026	−0.133	0.027
September	−0.045	0.025	−0.047	0.025
October	0.024	0.027	0.023	0.027
November	0.078	0.023	0.079	0.024
December	0.159	0.020	0.159	0.020
Cargo dummies, 46	Included		Included	
R^2	0.8669		0.8644	

The dependent variable is the logarithm of the price per tonne. The results are based on data from the Vaart!Vrachtindicator (2003–2007).

respect to the unit transport price, because the transport price is unlikely to affect the presence of sea ports. Hence, the exclusion restriction is that the presence of sea ports has no direct effect on transport prices, conditional on transport flows.

The port dummies are not only exogenous, one may expect that they are also strong predictors of the region imbalance difference. In Europe, seaports such as Rotterdam and Antwerp import more bulk cargo from overseas locations than they export to these locations, because industries in the hinterland of those seaports use large quantities of bulk cargo as inputs in their production processes and deliver manufactured goods as output. This implies that more bulk cargo is transported from the seaports to the hinterland regions than in the opposite direction.

The strength of the instruments has been examined by regressing the logarithm of the region imbalance difference on the control variables X_{rijt} and the two sea port dummies. It turns out that the instrumental variables are highly significant, with a F-value of more than 100. In addition, when we exclude the route imbalance in the specification of the model (consistent with our results), such that the number of instruments exceeds the number of endogenous regressors, then a standard overidentification test shows that the two instruments are jointly valid (so they are internally consistent with each other).[12]

Using IV, the estimated region imbalance elasticity is 0.296 (s.e. 0.085), substantially higher than the elasticity of the OLS estimation 0.116 (s.e. 0.038). The results are shown in Table 3. A Hausman t-statistic ($t = 2.36$) implies that we reject the null hypothesis of exogeneity at the 95% confidence level, indicating that the OLS estimates of the region imbalance difference elasticity are inconsistent [see Wooldridge (2002, p. 120)]. If we focus on the route imbalance effect, we see that its impact on the transport price is rather limited in size and statistically insignificant given the IV approach (using OLS, the effect has even the 'wrong' sign, also indicating that IV is the superior approach). This finding is consistent with the observation that only a few carriers travel back and forth between regions.

Recall that I_{ij} is defined as I_i/I_j, and we use the logarithm of this variable. Our main result is therefore that the elasticity of I_{ij} with respect to the transport price is equal to 0.296. To understand the size of the effect, it is useful to consider a one standard deviation increase in the imbalance in the origin region, I_i, which is 0.39 (see Table 2). Assuming that I_i increases by one standard deviation (from its mean which is equal to 1.44), then the transport price for trips that depart from this region will be 7.0% higher. This has been calculated by $((1.44+0.39)/1.44)^{0.296}-1=0.07$. As the transport price includes the costs of navigation plus the time costs of loading and unloading (the handling costs of loading and unloading are paid for by the shipper), the calculated increase in transport price applies to the 'full' transport price. A similar calculation for an increase in I_j generates almost the same result but with the opposite sign: $((1.00+0.34)/1.00)^{-0.296}-1=-0.08$.

It is also interesting to study the joint effects of the imbalance in the origin region (I_i) and the destination region (I_j) focusing on opposite trips between the Rotterdam port area (where a large seaport is located) and the Neckar area. In the latter area, the (weighted) number of trips with cargo leaving the Neckar area is 34% lower than those arriving, whereas the (weighted) number of trips with cargo leaving the Rotterdam port

12 Note that this test is rather weak in the sense that both instruments represent similar variables. Still, one may interpret the test as a misspecification test.

area is 81% higher than those arriving. Comparing the two trips, the transport price of the trip from the Rotterdam port area to the Neckar area is 70% higher than the trip in the opposite direction due to the differences in imbalance in the origin region and the destination region.[13]

We will now briefly discuss the results for the control variables. It appears that the travel time elasticity is about 0.08, and the distance elasticity is about 0.69. The sum of these elasticities is less than one, suggesting economies of scale in terms of the length of the trip. The load factor elasticity is estimated to be about -0.42, implying lower prices per tonne at higher load factors. Furthermore, we find that the price decreases as the vessel size increases, indicating economies of vessel size. Stream direction does not appear to have an effect on prices given the IV estimates, consistent with the idea that prices reflect round-trip cost of transport between regions, and so the one-way cost of transport do not affect prices conditional on round-trip cost.

We find that low-water levels increase the transport costs for water levels lower than 260 cm, in line with Jonkeren et al. (2007). The effect is stronger for trips that pass Kaub than for trips that do not pass Kaub. The December dummy implies the existence of relatively high-transport prices in the month December confirming a phenomenon, which is well known in this sector (many inland waterway transport enterprises do not work at the end of the year for holiday reasons and they put their inland ship in maintenance. As a result, supply falls and transport prices rise). The barge-fuel price effect is not statistically significant even at the 10% level. Note that we control for a time trend and that, during the period analysed, fuel prices strongly correlate with this time trend, and so the fuel price effect is difficult to identify.

3.2. Sensitivity analyses

In this section, we test for the robustness of the reported effect of the region imbalance difference variable. To be more specific, we examine the sensitivity of the results with respect to the assumption that the effect of the logarithm of the imbalance variable for the origin region is equal in value (but with opposite signs) to the effect of the logarithm of the imbalance variable for the destination region (3.2.1), controls for cargo type (3.2.2), the number of kilometers navigated without cargo before a trip with cargo starts (3.2.3) and the value of the decay parameter γ used to estimate the weights (3.2.4).

3.2.1. Measuring imbalance: distinguishing between origin and destination regions

The region imbalance difference is measured as the ratio of the origin-and destination-region imbalances. However, it could be argued that this specification is too restrictive, and so we allow here for a separate impact of the origin and destination imbalance variables on the transport price. We find that the effect of the origin imbalance variable, $\log(I_i)$, is 0.332 (s.e. 0.109), and the destination imbalance variable, $\log(I_j)$, -0.229 (s.e. 0.082). In line with theory, the effect of the origin imbalance variable is positive, whereas the effect is negative for the destination imbalance variable. Furthermore, it appears that the sum of the coefficients is not statistically different from zero (the sum

13 $(((0.656 + 1.15)/0.656)^{0.296} - 1) + (((1.81 - 1.15)/1.81)^{-0.296} - 1) = 0.70.$

equals 0.103 with a standard error equal to 0.082) justifying the use of $\log(I_{ij})$ in the empirical analysis. The standard error of the sum of the coefficients is calculated using standard covariance rules.

3.2.2. Controls for cargo type

In the previous section, we have shown that our measure of the region imbalance difference has a strong positive effect on the transport price. We have controlled for cargo type, as it may be argued that the cargo transported affects the unit costs via the density (mass per volume) of the cargo. So, the cargo type is a relevant control variable, as there is correlation between region imbalance and cargo type (imbalance is region-specific but also the production of certain goods and raw materials is region-specific). However, one may argue that the effect of the type of good transported on the transport price, and therefore the region imbalance effect, is biased, because the type of good transported may be endogenous. For example, because of a decrease in transport prices, it may become profitable to transport certain goods that otherwise would not have been profitable to transport (e.g. bricks). A counterargument would be that demand for inland waterway transport is price inelastic as discussed earlier, and so it is not very likely that the cargo type is strongly endogenous with respect to the transport price.

In a sensitivity analysis, we have therefore excluded the 47 dummy controls for cargo type. The region imbalance difference effect is then equal to 0.274 (s.e. 0.089) (note that, in this analysis, the region imbalance difference parameter may also be biased because of omitted-variable bias). Hence, our results are robust with respect to controlling for cargo type, indicating that this is a minor issue in the market analysed. Note that this issue is likely to be more relevant in the maritime transport market. For example, most of the goods, shipped from the Netherlands to China, appear to consist of used paper, which is transported at bottom transport prices.

3.2.3. Controlling for the distance navigated without cargo before starting a trip

We have argued earlier that due to differences in imbalance between regions, it will be frequently beneficial for carriers to navigate without cargo to a region with a more favourable imbalance. Therefore, trips that start from regions with an imbalance that is favourable for the carriers are likely to be preceded by a relatively long distance navigated without cargo. This conjecture is confirmed by a weak negative correlation between the natural logarithm of the distance navigated without cargo variable and the natural logarithm of the region imbalance difference variable. In a perfectly competitive transport market, the distance navigated without cargo before starting a paid trip should not have any effect when controlling for imbalance factors,[14] but, in a market with imperfections (e.g. search costs), the bargaining position of carriers may depend on this distance, and therefore affect the bargained transport price. It appears that controlling for distance navigated without cargo in the regression hardly affects the region imbalance difference coefficient (which is equal to 0.231 with an s.e. equal to

14 A shipper will choose the inland waterway transport company that offers the lowest price, and so an inland waterway transport company cannot ask a higher price if it has to navigate empty to the place of loading for a particular trip.

0.084). We find that the effect of distance navigated without cargo on the transport price is small with an elasticity of only 0.01.

3.2.4. Different values for the decay parameter

Recall that the value of the decay parameter γ has been estimated assuming an exponential distribution of the variable, which measures the distance navigated without cargo. γ is therefore equal to the inverse of the average distance navigated without cargo before starting a trip, which is slightly more than 95 km. We have examined the robustness of our results by assuming that the distance navigated without cargo is 70 or 110 km, implying a γ of 1/70 and 1/110, respectively. This range of γ seems reasonable, because very small values for γ imply that navigating without cargo is costless, whereas very large values for γ imply that navigating without cargo is prohibitively expensive. Both implications are unrealistic and inconsistent with the data. Thus, extreme values for γ are not realistic. We find that the results and, in particular, the effect of the imbalance in the origin region on the transport price remain essentially unaltered for these other values for γ. An increase of one standard deviation in the ratio of the export and import cargo flows in the origin region (I_i) now results in an increase of 6.3% (if $\gamma = 1/70$) and 7.7% (if $\gamma = 1/110$) of the transport price.

4. Conclusion

In the extensive literature on (regional and international) trade and regional activity, it is common to assume that transport costs are exogenous, but recently a new literature has emerged which argues that these transport costs are endogenous. For example, Behrens et al. (2006) make the assumption that unit transport prices negatively depend on trade volume using density economies arguments. In the current work, we also argue that transport costs are endogenous, but use an entirely different argument. Our argument is that transport costs depend on imbalances in trade flows, because carriers have to return to high demand regions without paid cargo. This implies that, ceteris paribus, unit transport prices positively depend on trade.

Here, we have studied this effect empirically using an ongoing survey for carriers in the inland waterway transport spot market in North West Europe, which covers mainly the Netherlands and Germany. Between these two countries, about 50% of all physical trade is transported by inland waterways, and so the price formation in the inland waterway transport market is fundamental to our understanding of the cost of trade between these two countries. The survey provides not only information about transport prices for each trip, but also detailed micro-information about a large number of control variables.

One important difference between the current study and existing empirical maritime transport studies is that the latter studies measure density economies by means of the size of the flow on routes (volume) and do not take into account the potential endogeneity of the imbalance variable, whereas in our empirical application, we control for density economies by means of several variables (vessel size, load factor and travel time) and emphasize that transport costs are endogenous with respect to the imbalance in export and import cargo flows in regions (the 'region imbalance'). Although standard transport economic theory on pricing of transport services within a two-region setting motivates our study, we have argued that in the case of a multi-region network where carriers cruise for shipments, a measure of trade imbalances at the level of the route may be less appropriate than a measure of imbalances at the level of the region. In our empirical application, we use both measures.

Our first finding is that regional imbalances play a much more prominent role than route imbalances in the determination of transport prices in the market analysed. Our main finding is that a one standard deviation increase in the ratio of the export and import cargo flows in the region of origin increases the price for inland waterway transport from this region by about 7%. A range of sensitivity analyses show that this effect is robust.

It is difficult to compare this result with those of other empirical studies because of differences in measurement of imbalance, and because endogeneity of imbalance is not taken into account.[15]

The inland waterway transport market we have studied covers 'exporting' regions (regions from which more trips with cargo depart than arrive) along the North Sea coast and 'importing' regions in the hinterland. The exporting regions include the seaports of Amsterdam, Rotterdam and Antwerp. Most bulk cargo enters Europe from sea via these ports and is then transported further to the hinterland making use of inland waterway transport. The hinterland regions do not export bulk goods on a large scale (they tend to export manufactured goods and services) to the sea-port regions. Hence, the 'physical' transport flow and therefore the number of inland waterway transport trips with cargo between seaports and hinterland is very unbalanced. One of the main consequences is that unit prices for transport from the seaports to the hinterland are substantially higher than the other way round.

Our results also have important implications for studies on international trade as reviewed by Anderson and van Wincoop (2004). Our study makes a strong case that transport prices from the Netherlands to Germany are substantially higher than the other way round, 'because' the Netherlands transports much more to Germany than the other way around. We can only speculate to what extent our results also hold for trade between other countries, but it is plausible that our results also hold more generally.

Acknowledgements

We are very grateful to Dirk van der Meulen for the Vaart!Vrachtindicator-data. We thank Steven Brakman for useful comments, RIZA, for data on water levels and Mrs van Helvoirt of the CBRB for the data on fuel prices. Jos van Ommeren would like to thank the Frisch Centre, Oslo, Norway, for its hospitality. This article is written in the framework of the Dutch national research programme "Climate *changes* Spatial Planning" and the NWO programme "Vulnerability, Adaptation and Mitigation".

Funding

Netherlands Organization for Scientific Research (NWO).

15 Nevertheless, we mention a few reported effects. Clark et al. (2004) find that a 100% point decrease in imbalance (defined as US exports—US import divided by bilateral trade) increases transport costs by about 6%. Wilmsmeier et al. (2006) report that an increase of the ratio of the volume of imports of country *i* from country *j* over the volume of exports from county *i* to country *j* by one point will lead to an increase in the freight costs by 0.05%. For details on the exact interpretation of the coefficients, we refer to the mentioned studies (also see Blonigen and Wilson, 2008).

References

Anderson, J. E. (2008) Economic integration and the civilising commerce hypothesis. *The World Economy*, 31: 141–157.

Anderson, J. E., van Wincoop, E. (2004) Trade costs. *Journal of Economic Literature*, XLII: 691–751.

Behrens, K., Gaigné, C. (2006) Density economies in transportation: revisiting the core-periphery model. *Economics Bulletin*, 18: 1–7.

Behrens, K., Picard, P. M. (2008) Transportation, freight rates, and economic geography. CORE Discussion Paper, 2008/4.

Behrens, K., Gaigné, C., Ottaviano, G. I. P., Thisse, J.-F. (2006) How density economies in international transportation link the internal geography of trading partners. *Journal of Urban Economics*, 60: 148–263.

Behrens, K., Gaigné, C., Thisse, J.-F. (2009) Industry location and welfare when transport costs are endogenous. *Journal of Urban Economics*, 65: 195–208.

Blonigen, B. A., Wilson, W. W. (2008) Port efficiency and trade flows. *Review of International Economics*, 16: 21–36.

Boarnet, M. G. (1994a) An empirical model of intrametropolitan population and employment growth. *Papers in Regional Science*, 73: 135–152.

Boarnet, M. G. (1994b) The monocentric model and employment location. *Journal of Urban Economics*, 36: 79–97.

Boyer, K. D. (1998) *Principles of Transportation Economics*. Reading, MA: Addison-Wesley.

Brueckner, J. K., Dyer, N. J., Spiller, P. T. (1992) Fare determination in airline hub-and-spoke networks. *The Rand Journal of Economics*, 23: 309–333.

CBS (2008) *Statline*. Central Bureau of Statistics. The Netherlands: The Hague.

CCNR (2007) European Commission. *Market observation for inland navigation in Europe, 2007-1*, Central Commission for Navigation of the Rhine, Strasbourg.

Clark, X., Dollar, D., Micco, A. (2004) Port efficiency, maritime transport costs, and bilateral trade. *Journal of Development Economics*, 75: 417–450.

Duranton, D., Storper, M. (2008) Rising trade costs? Agglomeration and trade with endogenous transaction costs. *Canadian Journal of Economics*, 41: 292–319.

Jonkeren, O., Rietveld, P., van Ommeren, J. (2007) Climate change and inland waterway transport. *Journal of Transport Economics and Policy*, 41: 387–411.

Krugman, P. (1991) Increasing returns and economic geography. *The Journal of Political Economy*, 99: 483–499.

Krugman, P. (1998) What's new about the new economic geography? *Oxford Review of Economic Policy*, 14: 7–17.

Limão, N., Venables, A. J. (2001) Infrastructure, geographical disadvantage, transport costs, and trade. *The World Bank Economic Review*, 15: 451–479.

Márquez-Ramos, L., Martínez-Zarzoso, I., Pérez-Garcia, E., Wilmsmeier, G. (2005) Determinants of maritime transport costs. Importance of connectivity measures. In Le Havre (ed.) *International Trade and Logistics, Corporate Strategies and the Global Economy Congress Proceedings*. September.

Moulton, B. R. (1990) An illustration of a pitfall in estimating the effects of aggregate variables on micro units. *The Review of Economics and Statistics*, 72: 334–338.

Neary, J. T. (2001) Of hype and hyperbolas: introducing the new economic geography. *Journal of Economic Literature*, 39: 536–561.

Ottaviano, G. I. P., Puga, D. (1998) Agglomeration in the global economy: a survey of the new economic geography. *The World Economy*, 21: 707–731.

Pigou, A. C. (1913) Railway rates and joint costs. *The Quarterly Journal of Economics*, 27: 687–694.

Rice, P., Venables, A. J., Patacchini, E. (2006) Spatial determinants of productivity: analysis for the UK regions. *Regional Science and Urban Economics*, 36: 727–752.

Sánchez, R. J., Hoffmann, J., Micco, A., Pizzolitto, G. V., Sgut, M., Wilmsmeier, G. (2003) Port efficiency and international trade: port efficiency as a determinant of maritime transport costs. *Maritime Economics and Logistics*, 5: 199–218.

Sjostrom, W. (2004) Ocean shipping cartels: a survey. *Review of Network Economics*, 3: 107–134.

TLN (2007) *Transport in Cijfers*, editie 2007. Zoetermeer: Transport en Logistiek Nederland.
Verbeek, M (2000) *A Guide To Modern Econometrics*. Chichester: Wiley.
Wilmsmeier, G., Hoffmann, J., Sánchez, R. J. (2006) The impact of port characteristics on international maritime transport costs. *Research in Transportation Economics*, 16: 117–140.
Wooldridge, J. M. (2002) *Econometric Analysis of Cross Section and Panel Data*. Cambridge, MA: MIT Press.

Appendix

Table A1. Imbalance by region, I_i

Region	I_i	$\log(I_i)$	nr. in map
Rotterdam port area (NL)	1.811	0.594	13
Amsterdam port area (NL)	1.649	0.500	12
Netherlands, South (NL)	1.626	0.486	11
Antwerp port area (B)	1.409	0.343	14
Netherlands, Centre (NL)	1.154	0.143	10
Netherlands, North (NL)	1.060	0.058	9
Upper Rhine area (D, F, CH)	1.002	0.002	1
Main and Danube (D, A, H)	0.960	−0.041	3
North German Canals (D)	0.923	−0.08	15
Ruhr area (D)	0.829	−0.187	6
Netherlands, East (NL)	0.811	−0.21	8
Middle Rhine area (D)	0.808	−0.213	4
West German Canals (D)	0.746	−0.293	7
Moselle and Saar area (D, F)	0.742	−0.299	5
Neckar area (D)	0.656	−0.422	2

Note: NL = the Netherlands; B = Belgium; D = Germany; F = France; CH = Switzerland; A = Austria; H = Hungary.

Table A2. Descriptives of key variables of transports flows and trip data based on 16,584 observations (including trips for which the navigation direction is difficult to determine)

Variable	Minimum	Maximum	Mean	SD
M_{ij} (route imbalance)	0.01	100.00	7.16	14.91
$\log(M_{ij})$	−4.61	4.61	0.94	1.40
I_{ij} (region imbalance difference)	0.36	2.76	1.42	0.69
$\log(I_{ij})$	−1.02	1.02	0.21	0.55
I_i (region imbalance, origin)	0.66	1.81	1.30	0.42
$\log(I_i)$	−0.42	0.59	0.21	0.34
I_j (region imbalance, destination)	0.66	1.81	1.05	0.35
$\log(I_j)$	−0.42	0.59	−0.003	0.30
Price per tonne (in €)	0.85	54.55	7.53	5.05
Travel time (in days)	1.00	31.00	5.03	2.39
Distance trip (in km)	12.00	4000.00	520.27	284.00
Distance navigated without cargo (in km)	0.00	908.00	89.91	93.57

Source: The Vaart!Vrachtindicator (2003–2007).

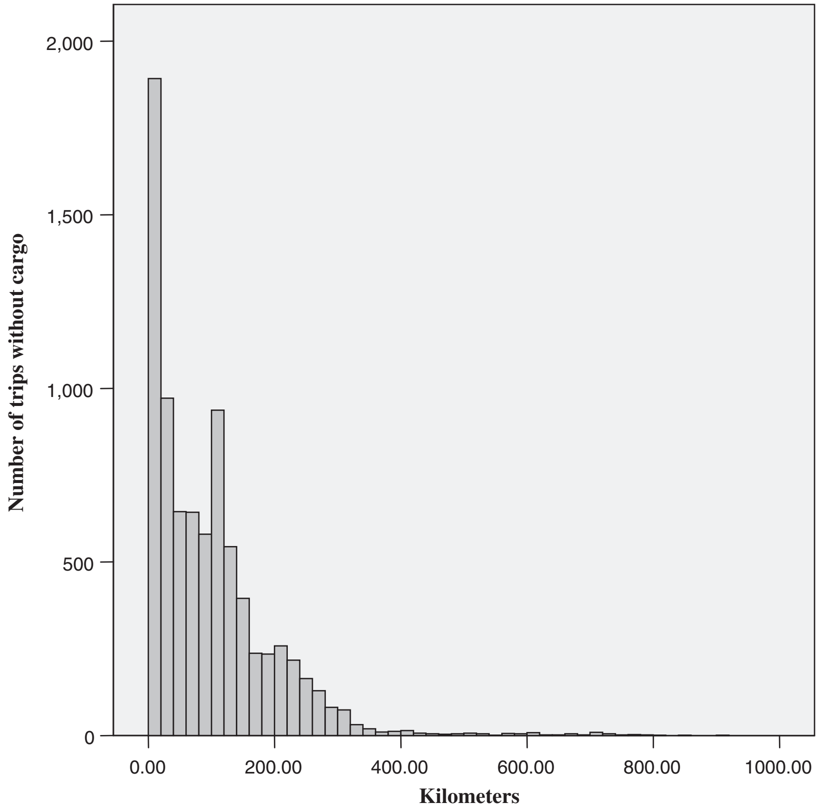

Figure A1. Distribution of distance navigated without cargo before starting a paid trip.
Note: Variable 'distance without cargo' is missing for observations in the period up to June 2004 as it was not included in the first 18 months of the survey. Therefore, the number of observations for this variable is 8177.